

R309-525. Conventional Surface Water Treatment (Effective December 16, 2002)

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R309-525. Conventional Surface Water Treatment.

R309-525-1. Purpose.

This rule specifies requirements for conventional surface water treatment plants used in public water systems. It is intended to be applied in conjunction with rules R309-500 through R309-550. Collectively, these rules govern the design, construction, operation and maintenance of public drinking water system facilities. These rules are intended to assure that such facilities are reliably capable of supplying adequate quantities of water which consistently meet applicable drinking water quality requirements and do not pose a threat to general public health.

R309-525-2. Authority.

This rule is promulgated by the Drinking Water Board as authorized by Title 19, Environmental Quality Code, Chapter 4, Safe Drinking Water Act, Subsection 104(1)(a)(ii) of the Utah Code and in accordance with 63-46a of the same, known as the Administrative Rulemaking Act.

R309-525-3. Definitions.

Definitions for certain terms used in this rule are given in R309-110 but may be further clarified herein.

R309-525-4. General.

(1) Treatment plants used for the purification of surface water supplies or ground water supplies under direct influence of surface water must conform to the requirements given herein. The plants shall have, as a minimum, facilities for flash mixing of coagulant chemicals, flocculation, sedimentation, filtration and disinfection.

(2) The overall design of a water treatment facility must be carefully examined to assure the compatibility of all devices and processes. The design of treatment processes and devices shall depend on an evaluation of the nature and quality of the particular water to be treated. The combined unit processes shall produce water meeting all established drinking water standards as given in R309-200.

(3) Direct filtration may be acceptable and rules governing this method are given in R309-530-5.

(4) Refer to R309-530-9 for policy with regards to novel water treatment equipment or techniques which may depart from the requirements outlined herein.

R309-525-5. Plant Capacity and Number of Treatment Trains.

(1) A determination of the required plant capacity and the required number of treatment trains shall be made after consultation with the Division. Ordinarily, a minimum of two units each for flocculation, sedimentation and filtration must be provided. The design shall provide for parallel or series operation of the clarification stages. Flash mix shall be designed and operated to provide a minimum velocity gradient of 750 fps/ft. Mixing time shall be less than thirty seconds. The treatment plant shall be designed to meet the anticipated "peak day demand" of the system being served when the treatment plant is the system's sole source. When other sources are available to the system, this requirement may be relaxed.

(2) The degree of "back-up" required in a water treatment plant will vary with the number of connections to be served, the availability of other acceptable sources of water, and the ability to control water consumption. Thus, when other sources are available to the system, the requirements of R309-525-7 (Plant Reliability) may also be relaxed. The Division shall be consulted in this regard prior to plant design.

R309-525-6. Plant Siting.

Plants must be sited with due regard for earthquake, flood, and fire hazard. Assistance in this matter is available from the Utah Geologic Survey. The Division shall be consulted regarding site selection prior to the preparation of engineering plans and specifications.

R309-525-7. Plant Reliability.

Plants designed for processing surface water or ground water under direct influence of surface water shall be designed to meet present and future water demands and assure reliable operation at all times. To help assure proper, uninterrupted operation:

(1) A manual override shall be provided for any automatic controls. Highly sophisticated automation may put proper maintenance beyond the capability of the plant operator, leading to equipment breakdowns or expensive servicing. Adequate funding must be assured for maintenance of automatic equipment.

(2) Main switch electrical controls shall be located above grade, in areas not subject to flooding.

(3) Plants shall be operated by qualified personnel approved by the Executive Secretary. As a minimum, the treatment plant manager is required to be certified in accordance with R309-300 at the grade of the waterworks system with an appropriate unrestricted Utah Operator's Certificate.

(4) The plant shall be constructed to permit units to be taken out of service without disrupting operation, and with drains or pumps sized to allow dewatering in a reasonable period of time.

(5) The plant shall have standby power available to permit operation of essential functions during power outages,

(6) The plant shall be provided with backup equipment or necessary spare parts for all critical items.

(7) Individual components critical to the operation of a treatment plant shall be provided with anchorage to secure the components from loss due to an earthquake event.

R309-525-8. Color Coding and Pipe Marking.

The piping in water treatment plants shall be color coded for identification. The following table contains color schemes recommended by the Division. Identification of the direction of flow and the contained liquid shall also be made on the pipe.

Table 525-1 Recommended Color Scheme for Piping	
Water Lines	
Raw	Olive Green
Settled or Clarified	Aquamarine
Finished	Dark Blue
Chemical Lines	
Alum	Orange
Ammonia	White
Carbon Slurry	Black
Chlorine (Gas and Solution)	Yellow
Flouride	Light Blue with Red Band
Lime Slurry	Light Green

Potassium Permanganate	Violet
Sulfur Dioxide	Light Green with Yellow Band
Waste Lines	
Backwash Waste	Light Brown
Sludge	Dark Brown
Sewer (Sanitary or Other)	Dark Grey
Other Lines	
Compressed Air	Dark Green
Gas	Red
Other Lines	Light Grey

R309-525-9. Diversion Structures and Pretreatment.

Refer to R309-515-5(5) for diversion structure design.

R309-525-10. Presedimentation.

Waters containing, heavy grit, sand, gravel, leaves, debris, or a large volume of sediments may require pretreatment, usually sedimentation, with or without the addition of coagulation chemicals.

- (1) Presedimentation basins shall be equipped for efficient sludge removal.
- (2) Incoming water shall be dispersed across the full width of the line of travel as efficiently as practical. Short-circuiting shall be minimized.
- (3) Provisions for bypassing presedimentation basins shall be included.

R309-525-11. Chemical Addition.

(1) Goals.

Chemicals used in the treatment of surface water shall achieve the following:

- (a) Primary coagulant chemicals shall be utilized to permit the formation of a floc,
- (b) Disinfectants shall be added to raw and/or treated water.

(2) Application Criteria.

In achieving these goals the chemical(s) shall be applied to the water:

- (a) To assure maximum control and flexibility of treatment,
- (b) To assure maximum safety to consumer and operators,
- (c) To prevent backflow or back-siphonage of chemical solutions to finished water systems.
- (d) With appropriate spacing of chemical feed to eliminate any interference between chemicals.

(3) Typical Chemical Doses.

Chemical doses shall be estimated for each treatment plant to be designed. "Jar tests" shall be conducted on representative raw water samples to determine anticipated doses.

(4) Information Required for Review.

With respect to chemical applications, a submittal for Division review shall include:

- (a) Descriptions of feed equipment, including maximum and minimum feed rates,
- (b) Location of feeders, piping layout and points of application,
- (c) Chemical storage and handling facilities,
- (d) Specifications for chemicals to be used,
- (e) Operating and control procedures including proposed application rates,
- (f) Descriptions of testing equipment and procedures, and

- (g) Results of chemical, physical, biological and other tests performed as necessary to define the optimum chemical treatment.

(5) Quality of Chemicals.

All chemicals added to water being treated for use in a public water system for human consumption shall comply with ANSI/NSF Standard 60. Evidence for this requirement shall be met if the chemical shipping container labels or material safety data sheets include:

- (a) Chemical name, purity and concentrations, Supplier name and address, and
- (b) Labeling indicating compliance with ANSI/NSF Standard 60.

Guidance: Blending and re-packaging of one or more certified chemicals by other than the original chemical supplier may void any laboratory certification and the Executive Secretary may require re-certification of such products before allowing their use.

(6) Storage, Safe Handling and Ventilation of Chemicals.

All requirements of the Utah Occupational Safety and Health Act (UOSHA) for storage, safe handling and ventilation of chemicals shall apply to public drinking water facilities. The designer shall incorporate all applicable UOSHA standards into the facility design, however, review of facility plans by the Division of Drinking Water under this Rule shall be limited to the following requirements:

(a) Storage of Chemicals.

- (i) Space shall be provided for:

- (A) An adequate supply of chemicals,
- (B) Convenient and efficient handling of chemicals,
- (C) Dry storage conditions.

- (ii) Storage tanks and pipelines for liquid chemicals shall be specific to the chemicals and not for alternates.

- (iii) Chemicals shall be stored in covered or unopened shipping containers, unless the chemical is transferred into a covered storage unit.

(iv) Liquid chemical storage tanks must:

(A) Have a liquid level indicator, and

(B) Have an overflow and a receiving basin or drain capable of receiving accidental spills or overflows, and meeting all requirements of R309-525-23, and

(C) Be equipped with an inverted "J" air vent.

(v) Acids shall be kept in closed acid-resistant shipping containers or storage units.

(b) Safe Handling.

(i) Material Safety Data Sheets for all chemicals utilized shall be kept and maintained in prominent display and be easily accessed by operators.

(ii) Provisions shall be made for disposing of empty bags, drums or barrels by an acceptable procedure which will minimize operator exposure to dusts.

(iii) Provisions shall be made for measuring quantities of chemicals used to prepare feed solutions.

(c) Dust Control and Ventilation.

Adequate provision shall be made for dust control and ventilation.

(7) Feeder Design, Location and Control.

(a) General Feeder Design.

General equipment design, location and control shall be such that:

(i) feeders shall supply, at all times, the necessary amounts of chemicals at an accurately controlled rate, throughout the anticipated range of feed,

(ii) chemical-contact materials and surfaces are resistant to the aggressiveness of the chemicals,

(iii) corrosive chemicals are introduced in a manner to minimize potential for corrosion,

(iv) chemicals that are incompatible are not fed, stored or handled together.

Guidance: Facilities should be such that chemicals can be located in a room separate from the main plant in order to reduce hazards and dust problems

(v) all chemicals are conducted from the feeder to the point of application in separate conduits,

(vi) spare parts are available for all feeders to replace parts which are subject to wear and damage,

(vii) chemical feeders are as near as practical to the feed point,

(viii) chemical feeders and pumps operate at no lower than 20 percent of the feed range,

(ix) chemicals are fed by gravity where practical,

(x) be readily accessible for servicing, repair, and observation.

(b) Chemical Feed Equipment.

Where chemical feed is necessary for the protection of the consumer, such as disinfection, coagulation or other essential processes:

(i) a minimum of two feeders, one active and one standby, shall be provided for each chemical,

(ii) the standby unit or a combination of units of sufficient capacity shall be available to replace the largest unit during shut-downs,

(iii) where a booster pump is required, duplicate equipment shall be provided and, when necessary, standby power,

(iv) a separate feeder shall be used for each non-compatible chemical applied where a feed pump is required, and

Guidance: If a common feeder is used for compatible chemicals such as alum and ferric, provisions should be made for flushing the lines and pumps prior to changing chemical.

(v) spare parts shall be available for all feeders to replace parts which are subject to wear and damage.

(c) Dry Chemical Feeders.

Dry chemical feeders shall:

- (i) measure feed rate of chemicals volumetrically or gravimetrically, and
- (ii) provide adequate solution water and agitation of the chemical in the solution tank.

(d) Feed Rate Control

- (i) Feeders may be manually or automatically controlled, with automatic controls being designed to allow override by manual controls.
- (ii) Chemical feed rates shall be proportional to flows.
- (iii) A means to measure water flow rate shall be provided.
- (iv) Provisions shall be made for measuring the quantities of chemicals used.
- (v) Weighing scales:
 - (A) shall be provided for weighing cylinders at all plants using chlorine gas,
 - (B) may be required for fluoride solution feed, where applicable,
 - (C) shall be provided for volumetric dry chemical feeders, and
 - (D) shall be accurate to measure increments of 0.5 percent of scale capacity.

(8) Feeder Appurtenances.

(a) Liquid Chemical Solution Pumps.

Positive displacement type solution feed pumps shall be used to feed liquid chemicals, but shall not be used to feed chemical slurries. Pumps must be sized to match or exceed maximum head conditions found at the point of injection. All liquid chemical feeders shall be provided with devices approved by the Utah Plumbing Code which will prevent the siphoning of liquid chemical through the pump.

(b) Solution Tanks.

(i) A means consistent with the nature of the chemical solution shall be provided in a solution tank to maintain a uniform strength of solution. Continuous agitation shall be provided to maintain slurries in suspension.

Guidance: Two solution tanks of adequate volume may be required for a chemical to assure continuity of supply while servicing a solution tank.

(ii) Means shall be provided to measure the solution level in the tank.

(iii) Chemical solutions shall be kept covered. Large tanks with access openings shall have the openings curbed and fitted with tight overhanging covers.

(iv) Subsurface locations are discouraged, but when used for solution tanks shall:

(A) be free from sources of possible contamination, and

(B) assure positive drainage for ground waters, accumulated water, chemical spills and overflows.

(v) Overflow pipes, when provided, shall:

(A) have a free fall discharge, and

(B) be located where noticeable.

(vi) Acid storage tanks shall be vented to the outside atmosphere, but not through vents in common with day tanks.

(vii) Each tank shall be provided with a valved drain, protected against backflow in accordance with R309-525-11(10)(b) and R309-525-11(10)(c).

(viii) Solution tanks shall be located and protective curbing provided so that chemicals from equipment failure, spillage or accidental drainage shall not enter the water in conduits, treatment or storage basins.

(ix) When polymers are used, storage tanks shall be located away from heat sources and direct sunlight.

(c) Day Tanks.

(i) Day tanks shall be provided where dilution of liquid chemical is required prior to feeding.

(ii) Day tanks shall meet all the requirements of R309-525-11(9)(b).

(iii) Certain chemicals, such as polymers, become unstable after hydration, therefore, day tanks shall hold no more than a thirty hour supply unless manufacturer's recommendations allow for longer periods.

(iv) Day tanks shall be scale-mounted, or have a calibrated gauge painted or mounted on the side if liquid levels cannot be observed in a gauge tube or through translucent sidewalls of the tank. In opaque tanks, a gauge rod extending above a referenced point at the top of the tank, attached to a float may be used. The ratio of the cross-sectional area of the tank to its height must be such that unit readings are meaningful in relation to the total amount of chemical fed during a day.

(v) Hand pumps may be provided for transfer from a carboy or drum. A top rack may be used to permit withdrawal into a bucket from a spigot. Where motor-driven transfer pumps are provided a liquid level limit switch and an overflow from the day tank, which will drain by gravity back into the bulk storage tank, must be provided.

(vi) A means which is consistent with the nature of the chemical solution shall be provided to maintain uniform strength of solution in a day tank. continuous agitation shall be provided to maintain chemical slurries in suspension.

(vii) Tanks shall be properly labeled to designate the chemical contained.

(d) Feed Lines.

(i) Feed lines shall be as short as possible in length of run, and be:

(A) of durable, corrosion resistant material,

(B) easily accessible throughout the entire length,

(C) protected against freezing, and

(D) readily cleanable.

(ii) Feed lines shall slope upward from the chemical source to the feeder when conveying gases.

(iii) Lines shall be designed with due consideration of scale forming or solids depositing properties of the water, chemical, solution or mixture conveyed.

(9) Make up Water Supply and Protection.

(a) In Plant Water Supply.

In plant water supply shall be:

(i) Ample in supply, adequate in pressure, and of a quality equal to or better than the water at the point of application.

(ii) Provided with means for measurement when preparing specific solution concentrations by dilution.

(iii) Properly protected against backflow.

Guidance: High calcium content in waters to be treated may interfere with the proposed treatment processes. In these instances, proper treatment for hardness should be provided.

(b) Cross-Connection Control.

Cross-connection control shall be provided to assure that:

(i) The make-up waterlines discharging to solution tanks shall be properly protected from backflow as required by the Utah Plumbing Code.

(ii) Liquid chemical solutions cannot be siphoned through solution feeders into the process units as required in R309-525-11(9)(c).

(iii) No direct connection exists between any sewer and the drain or overflow from the feeder, solution chamber or tank by providing that all pipes terminate at least six inches or two pipe diameters, whichever is greater, above the overflow rim of a receiving sump, conduit or waste receptacle.

(iv) Pre- and post-chlorination systems must be independent to prevent possible siphoning of partially treated water into the clear well. The water supply to each eductor shall have a separate shut-off valve. No master shut off valve will be allowed.

(c) Liquid Chemical Feeders, Siphon Control.

Liquid chemical feeders shall be such that chemical solutions cannot be siphoned into the process units, by:

- (i) Assuring positive pressure at the point of discharge,
- (ii) Providing vacuum relief,
- (iii) Providing a suitable air gap, or
- (iv) Other suitable means or combinations as necessary.

(10) Operator Safety.

Design of the plant shall be in accordance with the Utah Occupational Safety and Health Act (UOSHA). The designer and public water system management are responsible to see that they incorporate applicable UOSHA standards into the facility design and operation. Review of facility plans by the Division shall be limited to the following recommendations:

- (a) Floor surfaces should be smooth and impervious, slip-proof and well drained,
- (b) At least one pair of rubber gloves, a dust respirator of a type certified by the National Institute of Occupational Safety and Health (NIOSH) for toxic dusts, an apron or other protective clothing and goggles or face mask should be provided for each operator, A deluge shower and/or eye washing device should be installed where strong acids and alkalis are used or stored.
- (c) A water holding tank that will allow water to reach room temperature should be installed in the water line feeding the deluge shower and eye washing device. Other methods of water tempering may be available.
- (d) Adequate ventilation should be provided.

(11) Design for Specific Chemicals.

Design of the plant shall be in accordance with the Utah Occupational Safety and Health Act (UOSHA). The designer and public water system management are responsible to see that they incorporate applicable UOSHA standards into the facility design and operation. Review of facility plans by the Division shall be limited to the following recommendations:

Guidance: Chlorine Gas.

Precautions regarding chlorine gas are given in Sections R309-520-10 and R309-520-15.

Acids and Caustics.

- (i) Acids and caustics should be kept in closed corrosion-resistant shipping containers or storage units.
- (ii) Acids and caustics should not be handled in open vessels, but should be pumped in undiluted form from original containers through suitable hose, to the point of treatment or to a covered day tank.

Sodium Chlorite for Chlorine Dioxide Generation.

Proposals for the storage and use of sodium chlorite should be approved by the Executive Secretary prior to the preparation of final plans and specifications. Provisions should be made for proper storage and handling of sodium chlorite to eliminate any danger of explosion.

- (i) Sodium Chlorite Storage:
 - (A) Sodium chlorite should be stored by itself in a separate room and preferably should be stored in an outside building detached from the water treatment facility. It should be stored away from organic materials which would react violently with sodium chlorite;
 - (B) The storage structures should be constructed of noncombustible materials;
 - (C) If the storage structure is to be located in a area where a fire may occur, water should be available to keep the sodium chlorite

area sufficiently cool to prevent decomposition from heat and resultant potential explosive conditions.

(ii) Sodium Chlorite Handling:

(A) Care should be taken to prevent spillage;

(B) An emergency plan of operation should be available for the clean up of any spillage;

(C) Storage drums should be thoroughly flushed prior to recycling or disposal.

(iii) Sodium Chlorite Feeders:

(A) Positive displacement feeders should be provided;

(B) Tubing for conveying sodium chlorite or chlorine dioxide solutions should be Type 1 PVC, polyethylene or materials recommended by the manufacturer;

(C) Feed lines should be installed in a manner to prevent formation of gas pockets and should terminate at a point of positive pressure;

(D) Check valves should be provided to prevent the backflow of chlorine into the sodium chlorite line.

R309-525-12. Mixing.

(1) Flash Mix.

(a) Equipment - Mechanical, in-line or jet mixing devices shall be used.

(b) Mixing - All devices used in rapid mixing shall be capable of imparting a minimum velocity gradient (G) of at least 750 fps per foot. Mixing time shall be less than thirty seconds.

(c) Location - The flash mix and flocculation basins shall be as close together as possible.

(d) Introduction of chemicals - Primary coagulant chemicals shall be added at the point of maximum turbulence within the flash mix unit. Where in-line mixing devices are used chemical injection should be at the most appropriate upstream point.

(2) Flocculation.

(a) Basin design.

Inlet and outlet design shall prevent short-circuiting and destruction of floc. A drain or pumps shall be provided to handle dewatering and sludge removal.

(b) Detention.

The flow-through velocity shall not be less than 0.5 feet per minute nor greater than 1.5 feet per minute with a detention time for floc formation of at least 30 minutes.

(c) Equipment.

Agitators shall be driven by variable speed drives with the peripheral speed of paddles ranging from 0.5 fps to 2.0 fps. Equipment shall be capable of imparting a velocity gradient (G) between 25 fps per foot and 80 fps per foot to the water treated. Compartmentalized tapered energy flocculation concept may also be used in which G tapers from 100 fps to 10 fps per foot.

(d) Hydraulic flocculation.

Hydraulic flocculation may be permitted and shall be reviewed on a case by case basis. The unit must yield a G value equivalent to that required by b and c above.

(e) Piping.

Flocculation and sedimentation basins shall be as close as possible. The velocity of flocculated water through pipes or conduits to settling basins shall not be less than 0.5 fps nor greater than 1.5 fps. Allowance must be made to minimize turbulence at bends and changes in direction.

(f) Other designs.

Baffling may be used to provide for flocculation in small plants only after consultation with the Division. The design shall be such that the velocities and flows noted above will be maintained.

(g) Visible floc.

The flocculation unit shall be capable of producing a visible, settleable floc.

Guidance: If there is significant potential for intercepting wind-blown sediment or debris in the floc basin, a superstructure should be considered.

R309-525-13. Sedimentation.

(1) General Design Requirements.

Sedimentation shall follow flocculation. The detention time for effective clarification is dependent upon a number of factors related to basin design and the nature of the raw water. The following criteria apply to conventional sedimentation units:

(a) Inlet devices.

Inlets shall be designed to distribute the water equally and at uniform velocities. Open ports, submerged ports, or similar entrance arrangements are required. A baffle shall be constructed across the basin close to the inlet end and shall project several feet below the water surface to dissipate inlet velocities and provide uniform flows across the basin.

(b) Outlet devices.

Outlet devices shall be designed to maintain velocities suitable for settling in the basin and to minimize short-circuiting. The use of submerged orifices is recommended in order to provide a volume above the orifices for storage when there are fluctuations in the flow.

(c) Emergency Overflow.

An overflow weir (or pipe) shall be installed which will establish the maximum water level desired on top of the filters. It shall discharge by gravity with a free fall to a location where the discharge will be visible.

(d) Sludge Removal.

Sludge removal design shall provide that:

- (i) sludge pipes shall be not less than three inches in diameter and arranged to facilitate cleaning,
- (ii) entrance to sludge withdrawal piping shall prevent clogging,

- (iii) valves shall be located outside the basin for accessibility, and
- (iv) the operator may observe and sample sludge being withdrawn from the unit.
- (v) Sludge collection shall be accomplished by mechanical means.

(e) Drainage.

Basins shall be provided with a means for dewatering. Basin bottoms shall slope toward the drain not less than one foot in 12 feet where mechanical sludge collection equipment is not provided.

(f) Flushing lines.

Flushing lines or hydrants shall be provided and shall be equipped with backflow prevention devices acceptable to the Executive Secretary.

(g) Safety.

Appropriate safety devices shall be included as required by the Occupational Safety and Health Act (OSHA).

Guidance: Permanent ladders or handholds should be provided on the inside walls of basins above the water level

(h) Removal of floating material.

Provision shall be made for the periodic removal of floating material.

Guidance: If there is significant potential for intercepting wind-blown sediment or debris in the sedimentation basin, a superstructure should be considered

(2) Sedimentation Without Tube Settlers.

If tube settling equipment is not used within settling basins, the following requirements apply:

(a) Detention Time.

A minimum of four hours of detention time shall be provided. Reduced sedimentation time may be approved when equivalent effective settling is demonstrated or multimedia filtration is employed.

(b) Weir Loading.

The rate of flow over the outlet weir shall not exceed 20,000 gallons per day per foot of weir length. Where submerged orifices are used as an alternate for overflow weirs they shall not be lower than three feet below the water surface when the flow rates are equivalent to weir loading.

(c) Velocity.

The velocity through settling basins shall not exceed 0.5 feet per minute. The basins shall be designed to minimize short-circuiting. Fixed or adjustable baffles shall be provided as necessary to achieve the maximum potential for clarification.

(d) Depth.

The depth of the sedimentation basin shall be designed for optimum removal.

(3) Sedimentation With Tube Settlers

Proposals for settler unit clarification shall be approved by the Executive Secretary prior to the preparation of final plans and specifications.

Guidance: Settler units consisting of variously shaped tubes or plates which are installed in multiple layers and at an angle to the flow may be used for sedimentation following flocculation.

(a) Inlet and outlet design shall be such to maintain velocities suitable for settling in the basin and to minimize short circuiting.

(b) Flushing lines shall be provided to facilitate maintenance and be properly protected against backflow or back siphonage. Drain and sludge piping from the settler units shall be sized to facilitate a quick flush of the settler units and to prevent flooding other portions of the plant.

(c) Although most units will be located within a plant, design of outdoor installations shall provide sufficient freeboard above the top of settlers to prevent freezing in the units.

Guidance: A cover or enclosure is strongly recommended

(d) The design application rate shall be a maximum rate of 2 gal/sq.ft./min of cross-sectional area (based on 24-inch long 60 degree tubes or 39.5-inch long 7.5 degree tubes), unless higher rates are successfully shown through pilot plant or in-plant demonstration studies.

R309-525-14. Solids Contact Units.

(1) General.

Solids contact units are generally acceptable for combined softening and clarification where water characteristics, especially temperature, do not fluctuate rapidly, flow rates are uniform and operation is continuous. Before such units are considered as clarifiers without softening, specific approval of the Executive Secretary shall be obtained. A minimum of two units are required for surface water treatment.

Guidance: Clarifiers should be designed for the maximum uniform rate and should be adjustable to changes in flow which are less than the design rate and for changes in water characteristics.

(2) Installation of Equipment

The design engineer shall see that a representative of the manufacturer is present at the time of initial start-up operation to assure that the units are operating properly.

(3) Operation of Equipment.

The following shall be provided for plant operation:

- (a) a complete outfit of tools and accessories,
- (b) necessary laboratory equipment, and
- (c) adequate piping with suitable sampling taps so located as to permit the collection of samples of water from critical portions of the units.

(4) Chemical feed.

Chemicals shall be applied at such points and by such means as to insure satisfactory mixing of the chemicals with the water.

(5) Mixing.

A flash mix device or chamber ahead of solids contact units may be required to assure proper mixing of the chemicals applied. Mixing devices employed shall be so constructed as to:

- (a) provide good mixing of the raw water with previously formed sludge particles, and
- (b) prevent deposition of solids in the mixing zone.

(6) Flocculation.

Flocculation equipment:

- (a) shall be adjustable (speed and/or pitch),
- (b) shall provide for coagulation in a separate chamber or baffled zone within the unit, and
- (c) shall provide the flocculation and mixing period to be not less than 30 minutes.

(7) Sludge concentrators.

- (a) The equipment shall provide either internal or external concentrators in order to obtain a concentrated sludge with a minimum of waste water.
- (b) Large basins shall have at least two sumps for collecting sludge with one sump located in the central flocculation zone.

(8) Sludge removal.

Sludge removal design shall provide that:

- (a) sludge pipes shall be not less than three inches in diameter and so arranged as to facilitate cleaning,
- (b) the entrance to the sludge withdrawal piping shall prevent clogging,
- (c) valves shall be located outside the tank for accessibility, and
- (d) the operator may observe and sample sludge being withdrawn from the unit.

(9) Cross-connections.

- (a) Blow-off outlets and drains shall terminate and discharge at places satisfactory to the Executive Secretary.
- (b) Cross-connection control must be included for the finished drinking water lines used to back flush the sludge lines.

(10) Detention period.

The detention time shall be established on the basis of the raw water characteristics and other local conditions that affect the operation of the unit. Based on design flow rates, the detention time shall be:

- (a) two to four hours for suspended solids contact clarifiers and softeners treating surface water, and
- (b) one to two hours for suspended solids contact softeners treating only ground water.

(11) Suspended slurry concentrate.

Softening units shall be designed so that continuous slurry concentrates of one percent or more, by weight, can be satisfactorily maintained.

(12) Water losses.

- (a) Units shall be provided with suitable controls for sludge withdrawal.
- (b) Total water losses shall not exceed:
 - (i) five percent for clarifiers,

- (ii) three percent for softening units.
- (c) Solids concentration of sludge bled to waste shall be:
 - (i) three percent by weight for clarifiers,
 - (ii) five percent by weight for softeners.

(13) Weirs or orifices.

The units shall be equipped with either overflow weirs or orifices constructed so that water at the surface of the unit does not travel over 10 feet horizontally to the collection trough.

- (a) Weirs shall be adjustable, and at least equivalent in length to the perimeter of the basin.
- (b) Weir loading shall not exceed:
 - (i) 10 gpm per foot of weir length for units used for clarifiers
 - (ii) 20 gpm per foot of weir length for units used for softeners.
- (c) Where orifices are used the loading rates per foot of launderer shall be equivalent to weir loadings. Either shall produce uniform rising rates over the entire area of the tank.

(14) Upflow rates.

Upflow rates shall not exceed:

- (a) 1.0 gpm/sf at the sludge separation line for units used for clarifiers,
- (b) 1.75 gpm/sf at the slurry separation line for units used as softeners.

R309-525-15. Filtration.

(1) General.

Filters may be composed of one or more media layers. Mono-media filters are relatively uniform throughout their depth. Dual or multi-layer beds of filter material are so designed that water being filtered first encounters coarse material, and progressively finer material as it travels through the bed.

(2) Rate of Filtration.

(a) The rate of filtration shall be determined through consideration of such factors as raw water quality, degree of pretreatment provided, filter media, water quality control parameters, competency of operating personnel, and other factors as determined by the Executive Secretary. Generally, higher filter rates can be assigned for the dual or multi-media filter than for a single media filter because the former is more resistant to filter breakthrough.

(b) The filter rate shall be proposed and justified by the designing engineer to the satisfaction of the Executive Secretary prior to the preparation of final plans and specifications.

(c) The use of dual or multi-media filters may allow a reduction of sedimentation detention time (see R309-525-13(2)(a)) due to their increased ability to store sludge.

(d) Filter rates assigned by the Executive Secretary must never be exceeded, even during backwash periods.

(e) The use of filter types other than conventional rapid sand gravity filters must receive written approval from the Executive Secretary prior to the preparation of final plans and specifications.

(3) Number of Filters Required.

At least two filter units shall be provided. Where only two filter units are provided, each shall be capable of meeting the plant design capacity (normally the projected peak day demand) at the approved filtration rate. Where more than two filter units are provided, filters shall be capable of meeting the plant design capacity at the approved filtration rate with one filter removed from service. Refer to R309-525-5 for situations where these requirements may be relaxed.

(4) Media Design.

R309-525-15(4)(a) through R309-525-15(4)(e), which follow, give requirements for filter media design. These requirements are considered minimum and may be made more stringent if deemed appropriate by the Executive Secretary.

(a) Mono-media, Rapid Rate Gravity Filters.

The allowable maximum filtration rate for a silica sand, mono-media filter is three gpm/sf. This type of filter is composed of clean silica sand having an effective size of 0.35 mm to 0.65 mm and having a uniformity coefficient less than 1.7. The total bed thickness must not be less than 24 inches nor generally more than 30 inches.

(b) Dual Media, Rapid Rate Gravity Filters.

The following applies to all dual media filters:

(i) Total depth of filter bed shall not be less than 24 inches nor generally more than 30 inches.

(ii) All materials used to make up the filter bed shall be of such particle size and density that they will be effectively washed at backwash rates between 15 and 20 gpm/sf. They must settle to reconstitute the bed essentially in the original layers upon completion of backwashing.

(iii) The bottom layer must be at least ten inches thick and consist of a material having an effective size no greater than 0.45 mm and a uniformity coefficient not greater than 1.5.

(iv) The top layer shall consist of clean crushed anthracite coal having an effective size of 0.45 mm to 1.2 mm, and a uniformity coefficient not greater than 1.5.

(v) Dual media filters will be assigned a filter rate up to six gpm/sf. Generally if the bottom fine layer consists of a material having an effective size of 0.35 mm or less, a filtration rate of six gpm/sf can be assigned.

(vi) Each dual media filter must be provided with equipment which shall continuously monitor turbidity in the filtered water. The equipment shall be so designed to initiate automatic backwash if the filter effluent turbidity exceeds 0.3 NTU. If the filter turbidity exceeds one NTU, filter shutdown is required. In plants attended part-time, this shutdown must be

accomplished automatically and shall be accompanied by an alarm. In plants having full-time operators, a one NTU condition need only activate an alarm. Filter shutdown may then be accomplished by the operator.

Guidance: Due to increased media storage capacity the use of dual media filters may allow a reduction of detention time within sedimentation basins. Refer to R309-525-13(2)(a). Allowable reduction of sedimentation time will be determined by the Executive Secretary.

(c) Tri-Media, Rapid Rate Gravity Filters.

The following applies to all Tri-media filters:

- (i) Total depth of filter bed shall not be less than 24 inches nor generally more than 30 inches.
- (ii) All materials used to make up the filter bed shall be of such particle size and density that they will be effectively washed at backwash rates between 15 and 20 gpm/sf. They must settle to reconstitute the bed to the normal gradation of coarse to fine in the direction of flow upon completion of backwashing.
- (iii) The bottom layer must be at least four inches thick and consist of a material having an effective size no greater than 0.45 mm and uniformity coefficient not greater than 2.2. The bottom layer thickness may be reduced to three inches if it consists of a material having an effective size no greater than 0.25 mm and a uniformity coefficient not greater than 2.2.
- (iv) The middle layer must consist of silica sand having an effective size of 0.35 mm to 0.8 mm, and a uniformity coefficient not greater than 1.8.
- (v) The top layer shall consist of clean crushed anthracite coal having an effective size of 0.45 mm to 1.2 mm, and a uniformity coefficient not greater than 1.85.
- (vi) Tri-media filters will be assigned a filter rate up to 6 gpm/sf. Generally, if the bottom fine layer consists of a material having an effective size of 0.35 mm or less, a filtration rate of six gpm/sf can be assigned.
- (vii) Each Tri-media filter must be provided with equipment which shall continuously monitor turbidity in the filtered water. The equipment shall be so designed to initiate automatic backwash if the effluent turbidity exceeds 0.3 NTU. If the filter turbidity exceeds one NTU, filter shutdown is required. In plants attended part-time, this shutdown must be

accomplished automatically and shall be accompanied by an alarm. In plants having full-time operators, a one NTU condition need only activate an alarm. Filter shutdown may then be accomplished by the operator.

Guidance: Due to increased media storage capacity, the use of Tri-media filters may allow a reduction of detention time within sedimentation basins. Refer to R309-525-13(2)(a). Allowable reduction of sedimentation time will be determined by the Executive Secretary.

(d) Granulated Activated Carbon (GAC).

Use of granular activated carbon media shall receive the prior approval of the Executive Secretary, and must meet the basic specifications for filter material as given above, and:

- (i) There shall be provision for adding a disinfectant to achieve a suitable residual in the water following the filters and prior to distribution,
- (ii) There shall be a means for periodic treatment of filter material for control of biological or other growths,
- (iii) Facilities for carbon regeneration or replacement must be provided.

(e) Other Media Compositions and Configurations.

Filters consisting of materials or configurations not prescribed in this section will be considered on experimental data or available operation experience.

(5) Support Media, Filter Bottoms and Strainer Systems.

Care must be taken to insure that filter media, support media, filter bottoms and strainer systems are compatible and will give satisfactory service at all times.

(a) Support Media.

The design of support media will vary with the configuration of the filtering media and the filter bottom. Thus, support media and/or proprietary filter bottoms shall be reviewed on a case-by-case basis.

Guidance: Guidelines for two types of support media commonly used are as follows:

(1) Torpedo Sand- A three inch layer of torpedo sand should be used as a supporting media for the filter sand in single media filters and should have: (A) Effective size of 0.3 mm to 2.0 mm, and (B) Uniformity coefficient not greater than 1.7.

(2) Gravel- Gravel, when used as the supporting media, should consist of hard, rounded particles and should not include flat or elongated particles. The coarsest gravel should be 2.5 inches in size when the gravel rests directly on the strainer system, and should extend above the top of the perforated laterals. Not less than four layers of gravel should be provided in accordance with the following size and depth distribution when used with perforated laterals:

<i>Guidance Support Gravel</i>	
<i>Size</i>	<i>Depth</i>
<i>2-1/2 to 1-1/2 inches</i>	<i>5 to 8 inches</i>
<i>1-1/2 to 3/4 inches</i>	<i>3 to 5 inches</i>
<i>3/4 to 1/2 inches</i>	<i>3 to 5 inches</i>
<i>1/2 to 3/16 inches</i>	<i>2 to 3 inches</i>
<i>3/16 to 3/32 inches</i>	<i>2 to 3 inches</i>

(3) When proprietary filter bottoms are specified a reduction of gravel depths may be considered if such a reduction can be justified to the satisfaction of the Executive Secretary.

(b) Filter Bottoms and Strainer Systems.

(i) The design of manifold type collection systems shall:

- (A) Minimize loss of head in the manifold and laterals,
 - (B) Assure even distribution of washwater and even rate of filtration over the entire area of the filter,
 - (C) Provide a ratio of the area of the final openings of the strainer system to the area of the filter of about 0.003,
 - (D) Provide the total cross-sectional area of the laterals at about twice the total area of the final openings,
 - (E) Provide the cross-sectional area of the manifold at 1.5 to 2 times the total area of the laterals.
- (ii) Departures from these standards may be acceptable for high rate filter and for proprietary bottoms.
- (iii) Porous plate bottoms shall not be used where calcium carbonate, iron or manganese may clog them or with waters softened by lime.

(6) Structural Details and Hydraulics.

The filter structure shall be so designed as to provide for:

- (a) Vertical walls within the filter,
- (b) No protrusion of the filter walls into the filter media,
- (c) Cover by superstructure,
- (d) Head room to permit normal inspection and operation,
- (e) Minimum water depth over the surface of the filter media of three feet, unless an exception is granted by the Executive Secretary,
- (f) Maximum water depth above the filter media shall not exceed 12 feet,
- (g) Trapped effluent to prevent backflow of air to the bottom of the filters,
- (h) Prevention of floor drainage to enter onto the filter by installation of a minimum four inch curb around the filters,
- (i) Prevention of flooding by providing an overflow or other means of control,
- (j) Maximum velocity of treated water in pipe and conduits to filters of two fps,

- (k) Cleanouts and straight alignment for influent pipes or conduits where solids loading is heavy or following lime-soda softening,
- (l) Washwater drain capacity to carry maximum flow,
- (m) Walkways around filters, to be not less than 24 inches wide,
- (n) Safety handrails or walls around filter areas adjacent to normal walkways,
- (o) No common wall between filtered and unfiltered water shall exist. This requirement may be waived by the Executive Secretary for small "package" type plants using metal tanks of sufficient thickness,
- (p) Filtration to waste for each filter.

(7) Backwash.

(a) Water Backwash Without Air.

Water backwash systems shall be designed so that backwash water is not recycled to the head of the treatment plant unless it has been settled, as a minimum. Furthermore, water backwash systems; including tanks, pumps and pipelines, shall:

- (i) Provide a minimum backwash rate of 15 gpm/sf, consistent with water temperatures and the specific gravity of the filter media. The design shall provide for adequate backwash with minimum media loss. A reduced rate of 10 gpm/sf may be acceptable for full depth anthracite or granular activated carbon filters.

Guidance: A rate of 20 gpm/sf or a rate necessary to provide for a 50 percent expansion of the filter bed is recommended.

- (ii) provide finished drinking water at the required rate by washwater tanks, a washwater pump, from the high service main, or a combination of these.
- (iii) Permit the backwashing of any one filter for not less than 15 minutes.
- (iv) Be capable of backwashing at least two filters, consecutively.
- (v) Include a means of varying filter backwash rate and time.

- (vi) Include a washwater regulator or valve on the main washwater line to obtain the desired rate of filter wash with washwater valves or the individual filters open wide.
- (vii) Include a rate of flow indicator, preferably with a totalizer on the main washwater line, located so that it can be easily read by the operator during the washing process.
- (viii) Be designed to prevent rapid changes in backwash water flow.
- (ix) Use only finished drinking water.
- (x) Have washwater pumps in duplicate unless an alternate means of obtaining washwater is available.
- (xi) Perform in conjunction with "filter to waste" system to allow filter to stabilize before introduction into clearwell.

(b) Backwash with Air Scouring.

Air scouring can be considered in place of surface wash when:

- (i) air flow for air scouring the filter must be 3 to 5 scfm/sf of filter area when the air is introduced in the underdrain; a lower air rate must be used when the air scour distribution system is placed above the underdrains,
- (ii) a method for avoiding excessive loss of the filter media during backwashing must be provided,
- (iii) air scouring must be followed by a fluidization wash sufficient to restratify the media,
- (iv) air must be free from contamination,
- (v) air scour distribution systems shall be placed below the media and supporting bed interface; if placed at the interface the air scour nozzles shall be designed to prevent media from clogging the nozzles or entering the air distribution system.
- (vi) piping for the air distribution system shall not be flexible hose which will collapse when not under air pressure and shall not be a relatively soft material which may erode at the orifice opening with the passage of air at high velocity.

(vii) air delivery piping shall not pass down through the filter media nor shall there be any arrangement in the filter design which would allow short circuiting between the applied unfiltered water and the filtered water,

(viii) consideration shall be given to maintenance and replacement of air delivery piping,

(ix) when air scour is provided the backwash water rate shall be variable and shall not exceed eight gpm/sf unless operating experience shows that a higher rate is necessary to remove scoured particles from filter surfaces.

(x) the filter underdrains shall be designed to accommodate air scour piping when the piping is installed in the underdrain, and

(xi) the provisions of Section R309-525-15(7)(a) (Backwash) shall be followed.

(8) Surface Wash or Subsurface Wash.

Surface wash or subsurface wash facilities are required except for filters used exclusively for iron or manganese removal. Washing may be accomplished by a system of fixed nozzles or a revolving-type apparatus, provided:

(a) Provisions for water pressures of at least 45 psi,

(b) A properly installed vacuum breaker or other approved device to prevent back-siphonage if connected to a finished drinking water system,

(c) All washwater must be finished drinking water,

(d) Rate of flow of two gpm/sf of filter area with fixed nozzles or 0.5 gpm/sf with revolving arms.

(9) Washwater Troughs.

Washwater troughs shall be so designed to provide:

(a) The bottom elevation above the maximum level of expanded media during washing,

(b) A two inch freeboard at the maximum rate of wash,

(c) The top edge level and all edges of trough at the same elevation

(d) Spacing so that each trough serves the same number of square feet of filter areas,

(e) Maximum horizontal travel of suspended particles to reach the trough not to exceed three feet.

(10) Appurtenances.

(a) The following shall be provided for every filter:

(i) Sample taps or means to obtain samples from influent and effluent,

(ii) A gauge indicating loss of head,

(iii) A meter indicating rate-of-flow. A modified rate controller which limits the rate of filtration to a maximum rate may be used. However, equipment that simply maintains a constant water level on the filters is not acceptable, unless the rate of flow onto the filter is properly controlled,

(iv) A continuous turbidity monitoring device where the filter is to be loaded at a rate greater than three gpm/sf

(v) Provisions for draining the filter to waste with appropriate measures for backflow prevention (see R309-525-23)

Guidance: The following should be provided for every filter:

(1) Wall sleeves providing access to the filter interior at several locations for sampling or pressure sensing,

(2) A 1.0 inch to 1.5 inch diameter pressure hose and storage rack at the operating floor for washing filter walls.

(11) Miscellaneous.

Roof drains shall not discharge into filters or basins and conduits preceding the filters.

R309-525-16. In-Plant Finished Drinking Water Storage.

(1) General.

In addition to the following, the applicable design standards of R309-545 shall be followed for plant storage.

(a) Backwash Water Tanks.

Backwash water tanks shall be sized, in conjunction with available pump units and finished water storage, to provide the backwash water required by R309-525-15(7). Consideration shall be given to the backwashing of several filters in rapid succession.

(b) Clearwell.

Clearwell storage shall be sized, in conjunction with distribution system storage, to relieve the filters from having to follow fluctuations in water use.

(i) When finished water storage is used to provide the contact time for chlorine (see R309-520-10(1)(f), especially sub-section (f)(iv)), special attention must be given to size and baffling.

(ii) To ensure adequate chlorine contact time, sizing of the clearwell shall include extra volume to accommodate depletion of storage during the nighttime for intermittently operated filtration plants with automatic high service pumping from the clearwell during non-treatment hours.

(iii) An overflow and vent shall be provided.

(2) Adjacent Compartments.

Finished drinking water shall not be stored or conveyed in a compartment adjacent to unsafe water when the two compartments are separated by a single wall. The Executive Secretary may grant an exception to this requirement for small "package" treatment plants using metal tanks of sufficient wall thickness.

(3) Basins and Wet-Wells.

Receiving basins and pump wet-wells for finished drinking water shall be designed as drinking water storage structures. (See Section R309-545)

R309-525-17. Miscellaneous Plant Facilities.

(1) Laboratory.

Sufficient laboratory equipment shall be provided to assure proper operation and monitoring of the water plant. A list of required laboratory equipment is:

- (a) one floc testing apparatus with illuminated base and variable speed stirrer,
- (b) 10 each 1000 ml Griffin beakers (plastic is highly recommended over glass to prevent breakage),
- (c) one 1000 ml graduated cylinder (plastic is highly recommended over glass to prevent breakage),
- (d) pH test strips (6.0 to 8.5),
- (e) five wide mouth 25 ml Mohr pipets,
- (f) one triple beam, single pan or double pan balance with 0.1 g sensitivity and 2000 g capacity (using attachment weights),
- (g) DPD chlorine test kit,
- (h) bench-top turbidimeter,
- (i) five each 1000 ml reagent bottles with caps,
- (j) dish soap,
- (k) brush (2 3/4 inch diameter by 5 inch),
- (l) one platform scale 1/2 lb sensitivity, 100 lb capacity,
- (m) book - Simplified Procedures for Water Examination, AWWA Manual M12

(2) Continuous Turbidity Monitoring and Recording Equipment.

Continuous turbidity monitoring and recording facilities shall be located as specified in R309-215-9.

(3) Sanitary and Other Conveniences.

All treatment plants shall be provided with finished drinking water, lavatory and toilet facilities unless such facilities are otherwise conveniently available. Plumbing must

conform to the Utah Plumbing Code and must be so installed to prevent contamination of a public water supply.

R309-525-18. Sample Taps.

Sample taps shall be provided so that water samples can be obtained from appropriate locations in each unit operation of treatment. Taps shall be consistent with sampling needs and shall not be of the petcock type. Taps used for obtaining samples for bacteriological analysis shall be of the smooth-nosed type without interior or exterior threads, shall not be of the mixing type, and shall not have a screen, aerator, or other such appurtenance.

R309-525-19. Operation and Maintenance Manuals.

Operation and maintenance manuals shall be prepared for the treatment plant and found to be acceptable by the Executive Secretary. The manuals shall be usable and easily understood. They shall describe normal operating procedures, maintenance procedures and emergency procedures.

R309-525-20. Operator Instruction.

Provisions shall be made for operator instruction at the start-up of a plant.

R309-525-21. Safety.

All facilities shall be designed and constructed with due regard for safety, comfort and convenience. As a minimum, all applicable requirements of Utah Occupational Safety and Health Act (UOSHA) must be adhered to.

R309-525-22. Disinfection Prior To Use.

All pipes, tanks, and equipment which can convey or store finished drinking water shall be disinfected in accordance with the following AWWA procedures:

- (1) C651-99 Disinfecting Water Mains
- (2) C652-92 Disinfection of Water Storage Facilities
- (3) C653-97 Disinfection of Water Treatment Plants

R309-525-23. Disposal of Treatment Plant Waste.

Provisions must be made for proper disposal of water treatment plant waste such as sanitary, laboratory, sludge, and filter backwash water. All waste discharges and treatment facilities shall meet the requirements of the plumbing code, the Utah Department of Environmental Quality, the Utah Department of Health, and the United States Environmental Protection Agency, including the following:

- (1) Rules for Onsite Wastewater Disposal Systems, Utah Administrative Code R317-4.
- (2) Rules for Water Quality, Utah Administrative Code R317.
- (3) Rules for Solid and Hazardous Waste, Utah Administrative Code R315.

In locating waste disposal facilities, due consideration shall be given to preventing potential contamination of a water supply as well as breach or damage due to environmental factors.

R309-525-24. Other Considerations.

Consideration shall be given to the design requirements of other federal, state, and local regulatory agencies for items such as safety requirements, special designs for the handicapped, plumbing and electrical codes, construction in the flood plain, etc.

R309-525-25. Operation and Maintenance.

- (1) Water system operators must determine that all chemicals added to water intended for human consumption are suitable for drinking water use and comply with ANSI/NSF Standard 60.
- (2) No chemicals or other substances may be added to public water supplies unless the chemical addition facilities and chemical type have been reviewed and approved by the Executive Secretary. The Executive Secretary shall be notified prior to the changing of primary coagulant type. The Executive Secretary may require documentation to verify that sufficient testing and analysis have been done. The primary coagulant may not be changed without prior approval from the Executive Secretary.
- (3) During the operation of a conventional surface water treatment plant stable flow rates shall be maintained through the filters.

Guidance: Water should not be introduced into the system immediately after backwashing. Rather, water should be filtered to waste. A “dirty filter” should not be started and immediately introduced into the system. If the filter has sat idle for an

extended period, or if the filter is sufficiently “dirty”, backwash and filter to waste before introducing the water.

(4) All instrumentation needed to verify that treatment processes are sufficient shall be properly calibrated and maintained. As a minimum, this shall include turbidimeters.

KEY: drinking water, flocculation, sedimentation, filtration

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